This is a standalone specification intended for payload designers. Planetary Systems Corporation does not design or manufacture payloads.

1. FEATURES AND BENEFITS

- **Preloaded Payload Tabs** create a modelable load path to the payload so strength at critical locations like reaction wheel bearings can be accurately calculated. Preload means the payload can't jiggle and damage itself.
- **Separation Electrical Connector** allows communication and charging between payload and launch vehicle prior to and during launch. It also grounds the payload to the CSD
- **Dispenser Constrained Deployables** greatly reduce the costs and complexity of payload deployables like solar panels and antennas.
- **Largest Volume** versus existing designs accommodates larger payloads. Payloads have 15% more volume and can be 1 inch longer than standard CubeSats.
- **Unrestricted External Shape** eliminates need for four corner rails.
- **Safe/Arm Access on Front** ensures payload access at all times via CSD door.
- **Flight Validated** in 2013.
- **Fully Documented** mechanical and electrical interfaces and CAD models available on request allowing rapid and low cost design.
- **Parametric Design** commonality allows users easy understanding of electro-mechanical interface for 3U, 6U, 12U and 27U sizes.
- **Cross Compatible** with existing CubeSat standards via tab attachment.

2. DESCRIPTION

These payloads are fully contained within a Canisterized Satellite Dispenser (CSD, canister or dispenser) during launch. A CSD encapsulates the payload during launch and dispenses it on orbit. CSDs reduce risk to the primary payload and therefore maximize potential launch opportunity. They also ease restrictions on payload materials and components. This specification currently encompasses four payload sizes, 3U, 6U, 12U and 27U.

The payloads incorporate two tabs running the length of the ejection axis. The CSD will grip these tabs, providing a secure, modelable, preloaded junction. This is essential to accurately predict loads on critical components and instrumentation and prevent jiggling.

The payload may use the CSD to restrain deployables. The allowable contact zones are defined.

A payload can be built to this specification without knowledge of the specific dispenser within it will fly. Similarly, dispenser manufacturers will be ensured of compatibility with payloads that conform to this specification.

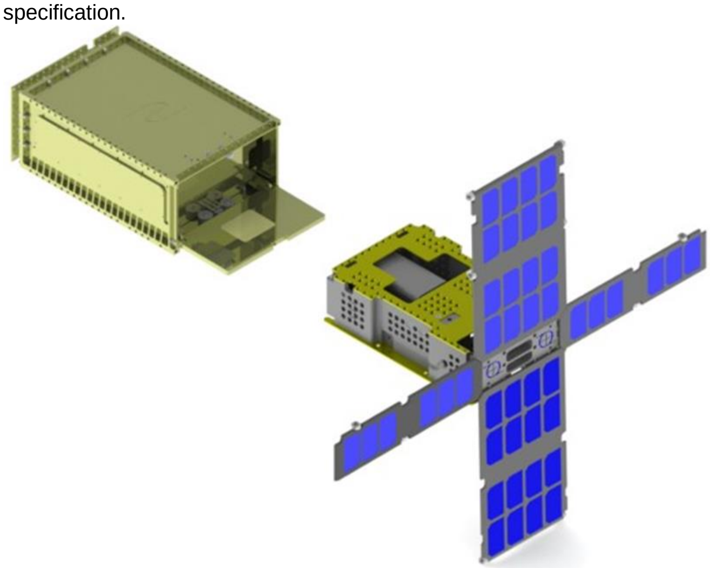


Figure 2-1: Payload Deploying from CSD

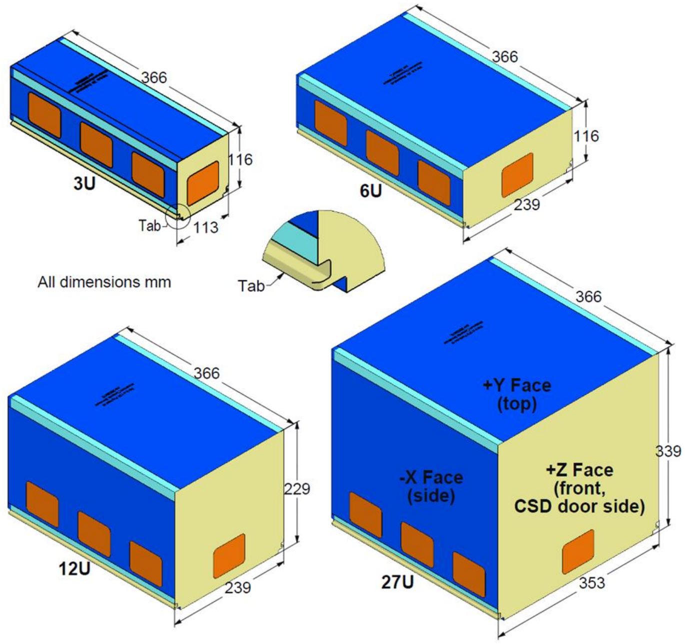


Figure 2-2: Payloads

CONTENTS

3. PARAMETERS

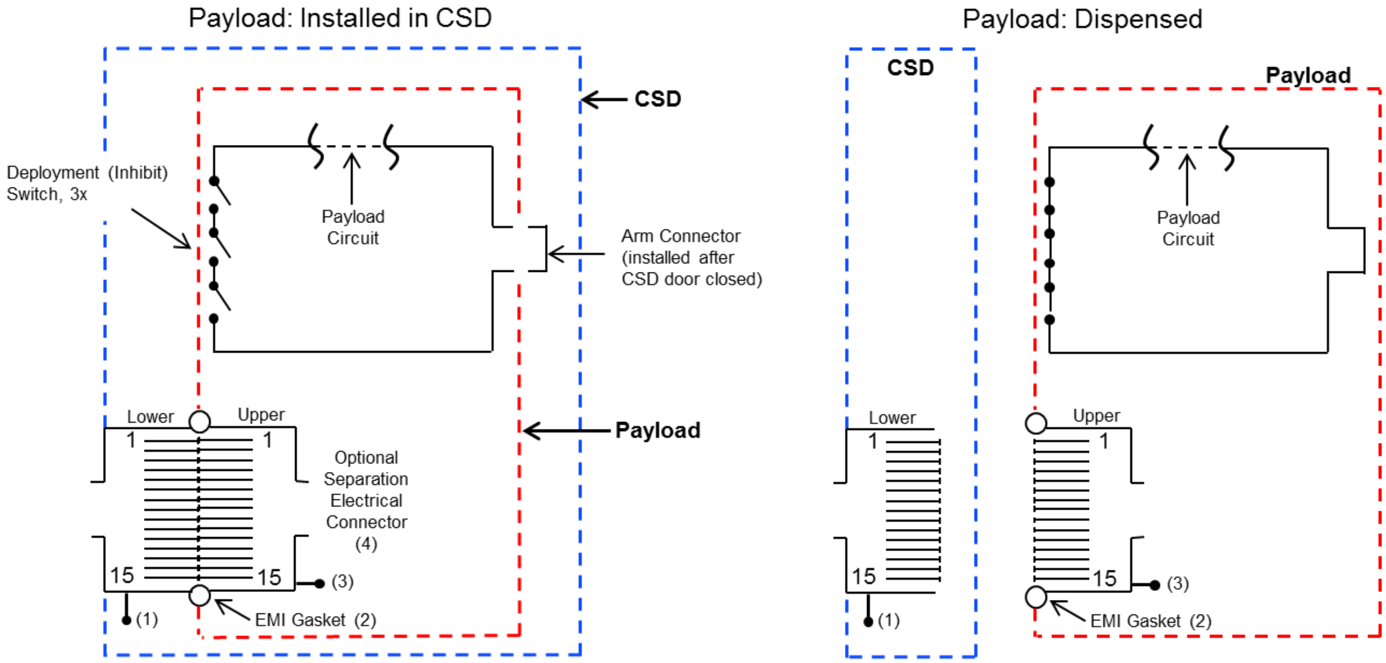
Symbol	Parameter	Conditions	Unit	3U		6U		12U		27U	
				Min	Max	Min	Max	Min	Max	Min	Max
M	Mass	At launch	kg [lb]	0	6.0 [13.2]	0	12.0 [26.4]	0	24.0 [52.9]	0	54.0 [119.0]
CM_X	Center of mass, X	Stowed in CSD	mm [in]	-20 [-0.79]	20 [0.79]	-40 [-1.57]	40 [1.57]	-40 [-1.57]	40 [1.57]	-60 [-2.36]	60 [2.36]
CM_Y	Center of mass, Y	Stowed in CSD	mm [in]	10 [0.39]	70 [2.76]	10 [0.39]	70 [2.76]	55 [2.17]	125 [4.92]	100 [3.94]	180 [7.09]
CM_Z	Center of mass, Z	Stowed in CSD	mm [in]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]	133 [5.24]	233 [9.17]
Height	Maximum payload depth, +Y dimension		mm [in]	0	109.7 [4.319]	0	109.7 [4.319]	0	222.8 [8.771]	0	332.8 [13.102]
Width	Maximum payload width from origin, ±X dimension		mm [in]	0	56.55 [2.226]	0	119.7 [4.713]	0	119.7 [4.713]	0	176.25 [6.939]
Tab Width	±X dimension		mm [in]	112.7 [4.437]	113.1 [4.453]	239.0 [9.409]	239.4 [9.425]	239.0 [9.409]	239.4 [9.425]	352.1 [13.862]	352.5 [13.878]
Tab Length	+Z dimension		mm [in]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]	361 [14.21]	366 [14.41]
EP_Y	Ejection plate contact zone, +Y dimension from origin		mm [in]	-	100 [3.94]	-	100 [3.94]	-	213 [8.39]	-	326 [12.84]
DC_X1	Deployable contact zone with CSD, ±X face near +Y face		mm [in]	91.4 [3.598]	-	91.4 [3.598]	-	204.5 [8.051]	-	317.6 [12.504]	-
DC_X2	Deployable contact zone with CSD, ±X face near -Y face		mm [in]	-	20.3 [0.799]	-	20.3 [0.799]	-	20.3 [0.799]	-	20.3 [0.799]
DC_+Y	Deployable contact zone with CSD, +Y face (1)		mm [in]	43.85 [1.726]	-	107.0 [4.213]	-	107.0 [4.213]	-	163.55 [6.439]	-
DC_-Y	Deployable contact zone with CSD, -Y face (1)		mm [in]	31.2 [1.228]	-	94.3 [3.713]	-	94.3 [3.713]	-	150.9 [5.941]	-
F_{DS}	Force from deployment switches, summated, Z axis	When contacting CSD ejection plate	N	0	5.0	0	5.0	0	5.0	0	5.0
D_{DS}	Payload separation from ejection plate necessary to change deployment switch state, Z axis		mm [in]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]	1.3 [0.05]	12.7 [0.50]
F_{FD}	Friction force deployables impart on CSD walls during ejection	summated (all 4 sides)	N	0	2.0	0	2.0	0	2.0	0	4.0
F_{ND}	Normal force deployables impart on CSD walls during ejection	per bearing contact	N	0	9.0	0	9.0	0	9.0	0	9.0
TML	Total Mass Loss	Per ASTM E 595-77/84/90	%	0	1.0	0	1.0	0	1.0	0	1.0
CVCM	Collected Volatile Condensable Material	Per ASTM E 595-77/84/90	%	0	0.1	0	0.1	0	0.1	0	0.1
DP	CSD de-pressurization rate	During launch	psi/ sec	0	0.5	0	0.5	0	0.5	0	0.5
D_X	Location of optional separation electrical connector, +X dimension		mm [in]	40.79 [1.601]	41.07 [1.621]	103.95 [4.088]	104.23 [4.108]	103.95 [4.088]	104.23 [4.108]	160.49 [6.314]	160.77 [6.334]

(1) Some contact zones are not present on the 3U. Refer to Figure 6-2 for locations.

4. COMMON REQUIREMENTS

1. Tabs shall be 100% continuous 7075-T7 aluminum alloy. Holes, countersinks, and any protruding features are prohibited anywhere along the Tabs. Other aluminum alloys of equivalent or stronger yield strength may be substituted. Tabs shall also be Hard Anodized per MIL-A-8625, Type III, Class 1. All dimensions apply AFTER hard anodize. Note that Anodize thickness refers to the total thickness (i.e. 0.001 total thickness = 0.0005 penetration + 0.0005 build-up). Max surface roughness of Tabs = 1.2 μm Ra.
2. Tabs shall run the entire length of the payload. No portion of the payload may extend beyond the tabs in the +Z or –Z directions.
3. Dimensions and tolerances in Figure 6-2 shall be maintained under all temperatures. Consider CTE warping of tabs if structure is not aluminum.
4. The structure comprising the –Z face (face that contacts CSD ejection plate) may be a uniform surface or consist of discrete contact points. The discrete contact points shall be located such that they envelope the payload's C.M. and any deployment switches.
5. At least one deployment (inhibit) switch is required. Some launch vehicles may require up to three. They shall reside in the specified zone on the -Z face. Switches will activate upon contact with CSD ejection plate.
6. Safe/Arm plug, if necessary, shall reside in specified zone on +Z (preferred), +X, or -X face.
7. All non-constrained deployables shall be hinged near the +Z face to minimize snagging hazards during ejection. The deployables shall be tested with the CSD prior to flight.
8. -Z face of payload shall withstand a 400 N force imparted by CSD ejection plate during launch due to vibration.
9. If electrical grounding to the CSD is desired, the Separation Electrical Connector (In-Flight Disconnect) must be used. See Ref. 3.
10. The two tabs and the structure that contacts the CSD ejection plate on the –Z face are the only required features of the payload. The rest of the payload may be any shape that fits within the max dynamic envelope.
11. The maximum dimensions stated in this document are the payload's dynamic envelope and shall include all load cases (vibration, thermal, acoustic, etc.).
12. No debris shall be generated that will inhibit separation.

5. ELECTRICAL SCHEMATIC



1) The metal shell conducts to the CSD via conductive surface treatments.
2) Required to assure electrical continuity between shells. Retained by Upper.
3) The metal shell conducts to the Payload via conductive surface treatments.
4) Optional connector is an in-flight disconnect. Produced by Planetary Systems Corp. See document 2001025 at www.planetarysys.com.

Figure 5-1: Electrical Schematic

6. DIMENSIONS

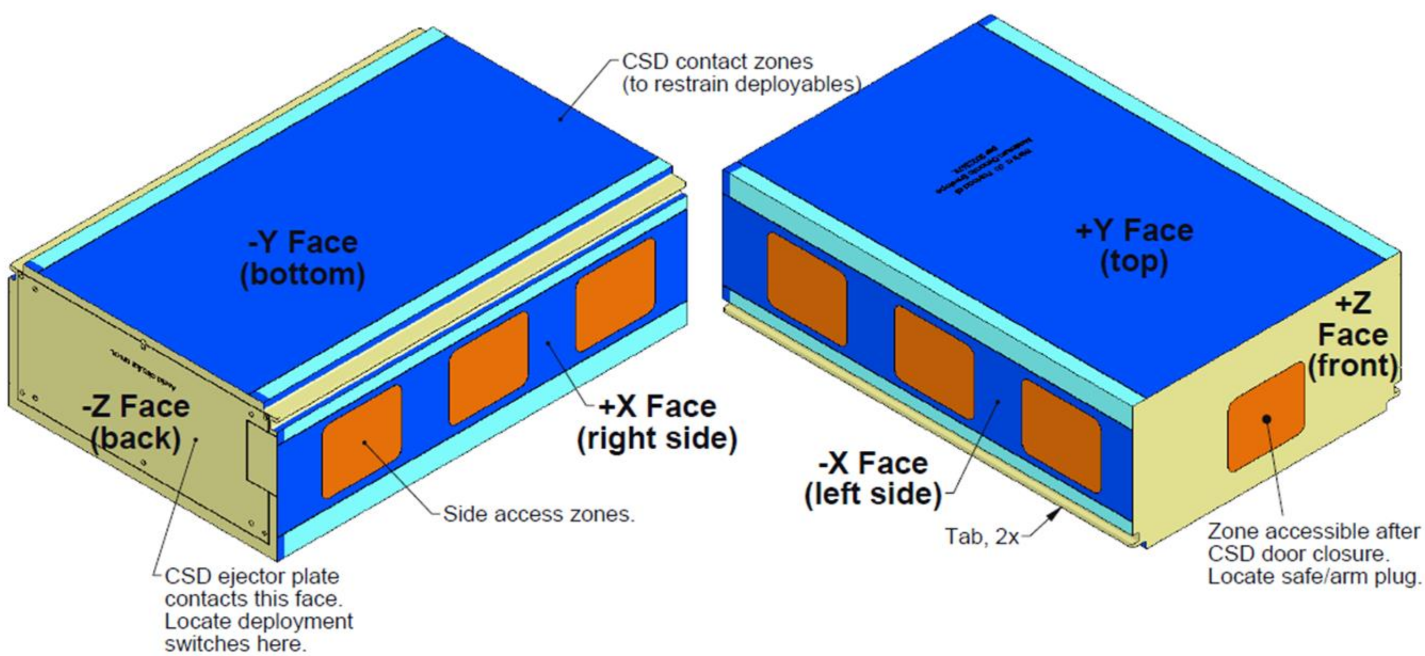
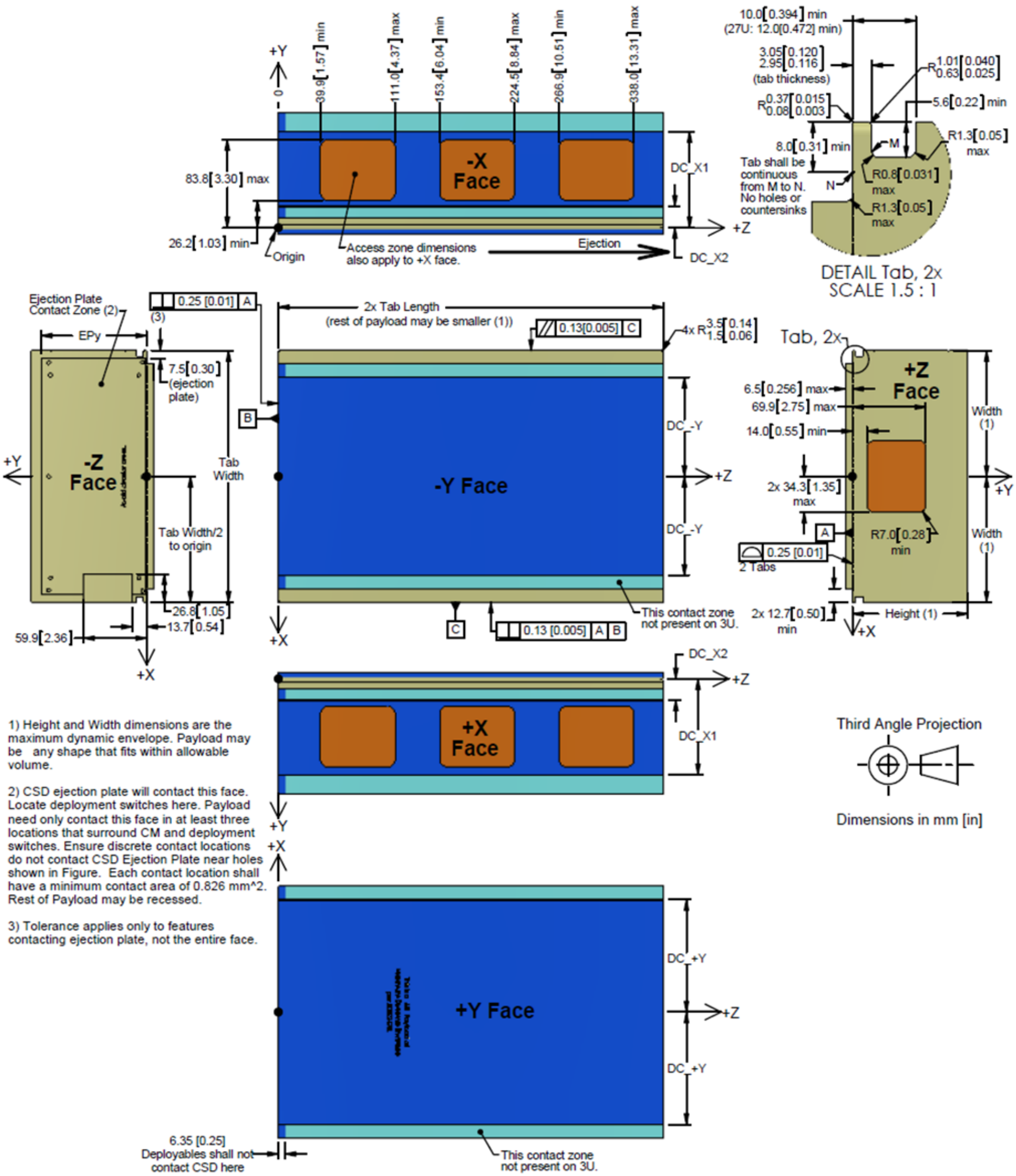


Figure 6-1: Payload Features (6U Shown)



1) Height and Width dimensions are the maximum dynamic envelope. Payload may be any shape that fits within allowable volume.

2) CSD ejection plate will contact this face. Locate deployment switches here. Payload need only contact this face in at least three locations that surround CM and deployment switches. Ensure discrete contact locations do not contact CSD Ejection Plate near holes shown in Figure. Each contact location shall have a minimum contact area of 0.826 mm^2. Rest of Payload may be recessed.

3) Tolerance applies only to features contacting ejection plate, not the entire face.

Figure 6-2: Payload Dimensions

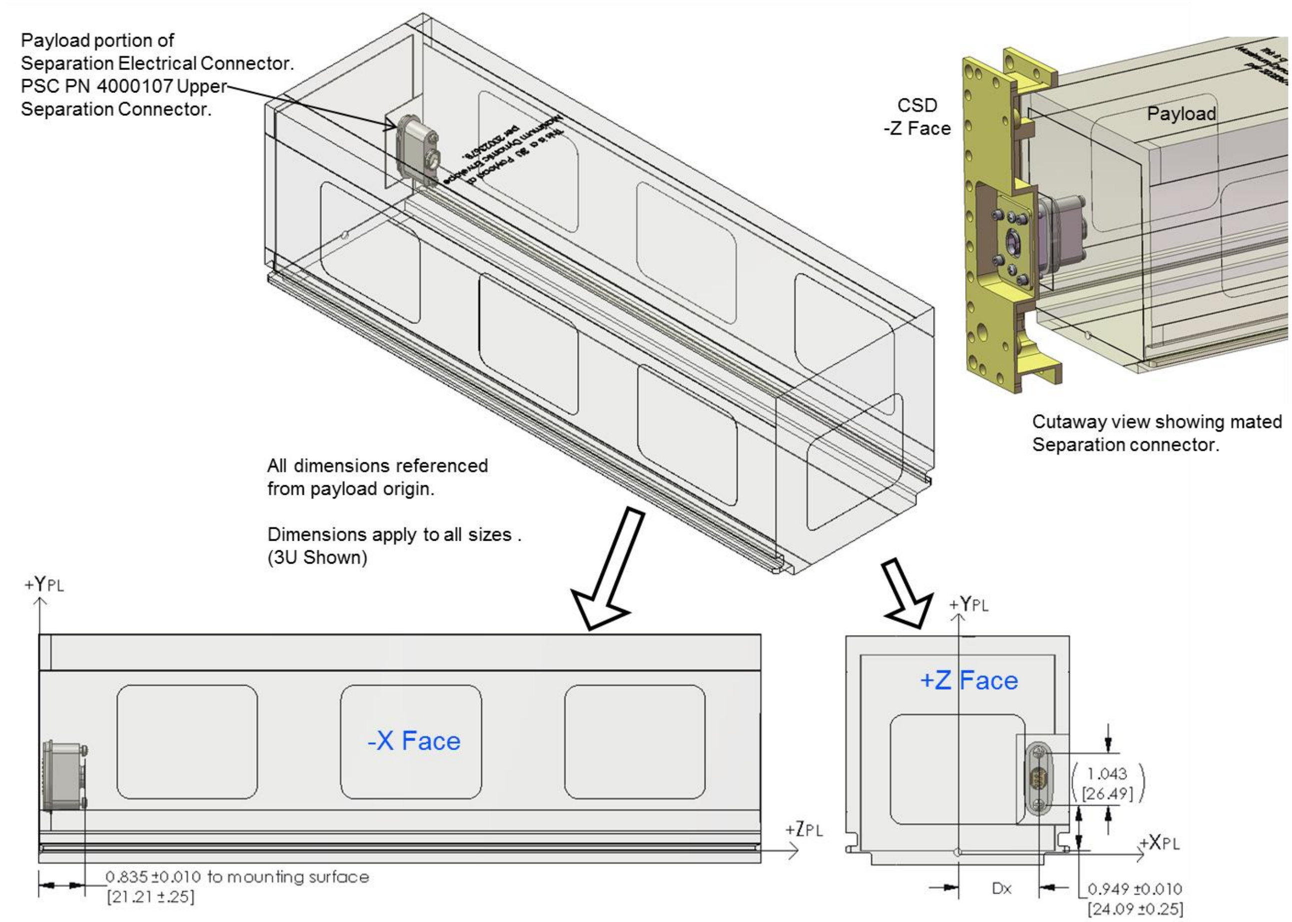
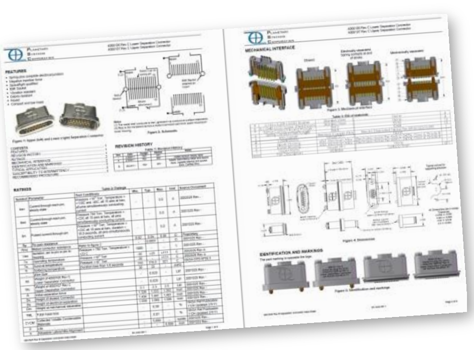


Figure 6-3: Location of Optional Separation Electrical Connector (In-Flight Disconnect)

For more information on the Separation Electrical Connector see PSC document 2001025 Separation Connector Data Sheet. Ref. 3. Also see section *Separation Electrical Connector Attachment.*



7. DISCRETE PAYLOADS

Multi-piece payloads are allowed provided they meet the following requirements.
1) Total length of all pieces: must comply with 'Tab Length' in Parameters Section.
2) Minimum allowable tab length of a single piece: 50mm [2.0 in].
3) Minimum tab gap between adjoining pieces (Z direction): 0.5mm [0.02 in].
4) Tab thickness of the extreme fore and aft pieces: equal to or greater than the adjoining piece.

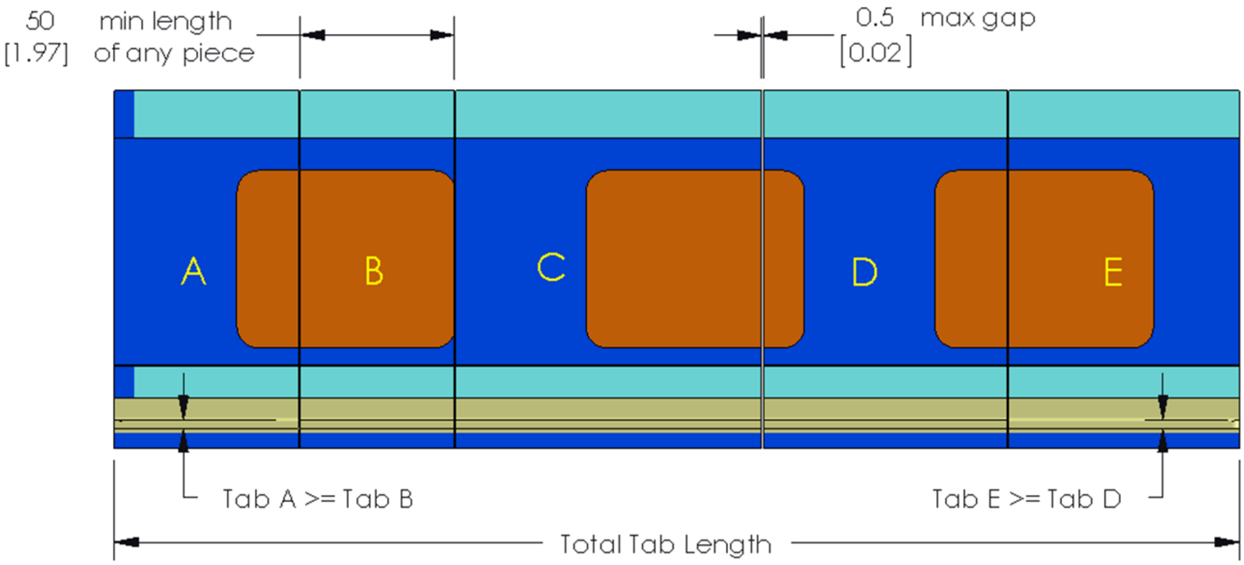


Figure 7-1: Generic Multi-Piece Payload (dimensions mm [in])

See Figure 14-2 and Figure 14-3 for examples of discrete payloads.

8. DESIGNS WITH TABS REMOVED

A payload can be designed with large tab gaps if necessary. This requires a CSD customization. Contact the CSD manufacturer if non-continuous tabs are desired.

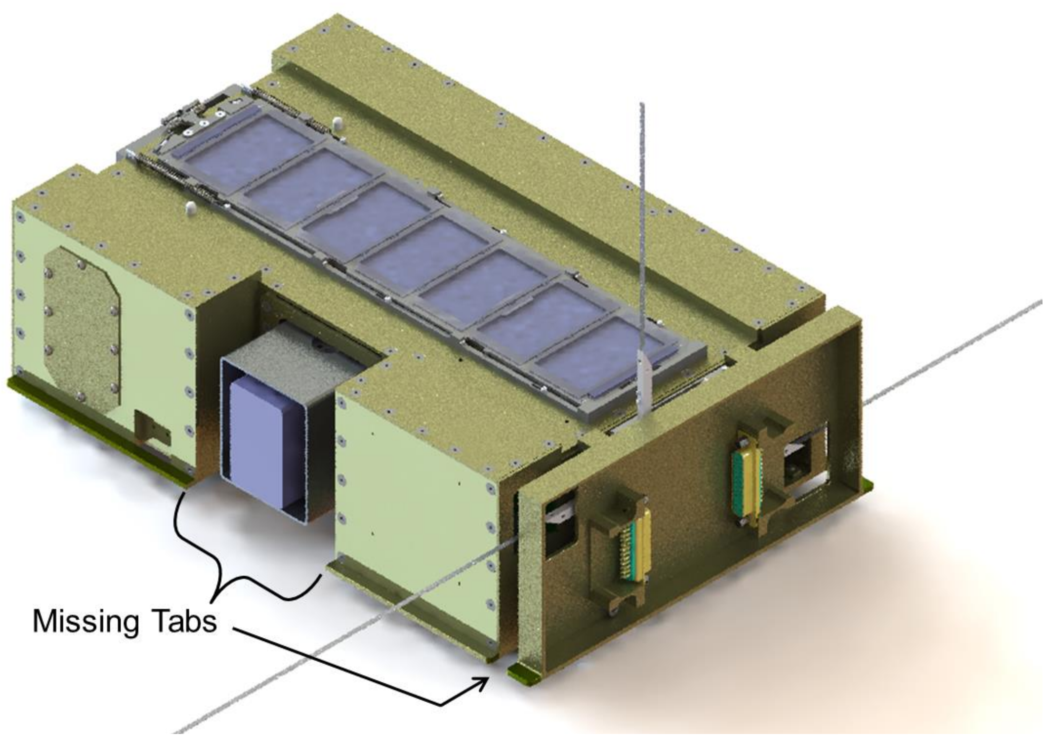


Figure 8-1: 6U Payload with Non-Continuous Tabs

9. BENEFIT OF TABS

Preloading the payload to the CSD by virtue of clamping the tabs creates a stiff invariant load path. This allows for accurate dynamic modeling to predict responses in anticipation of vibratory testing and space flight. Confidently predicting response is critical for aerospace structures and sensitive components. A payload that can move inside its dispenser is unmodelable and therefore the loading of sensitive components can not be predicted.

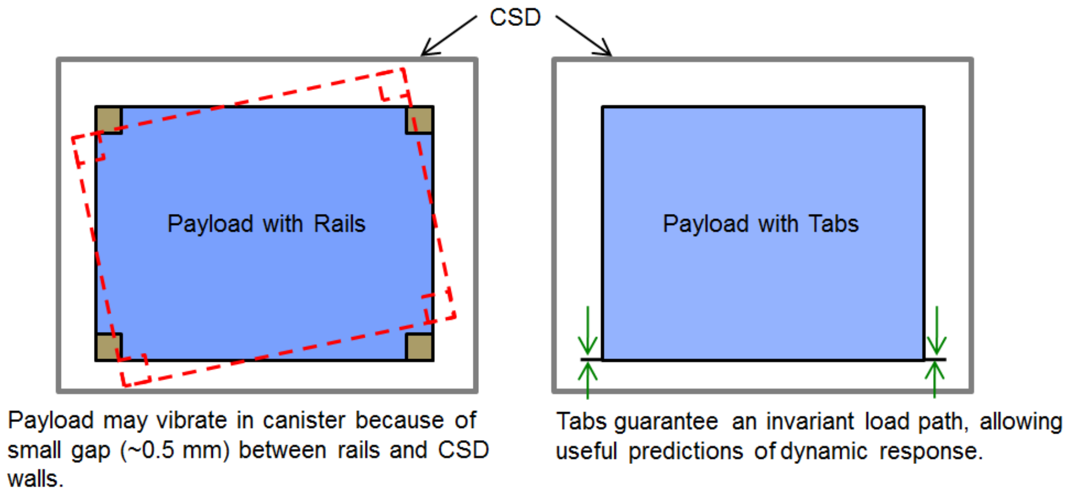


Figure 9-1: Tabs vs. Rails

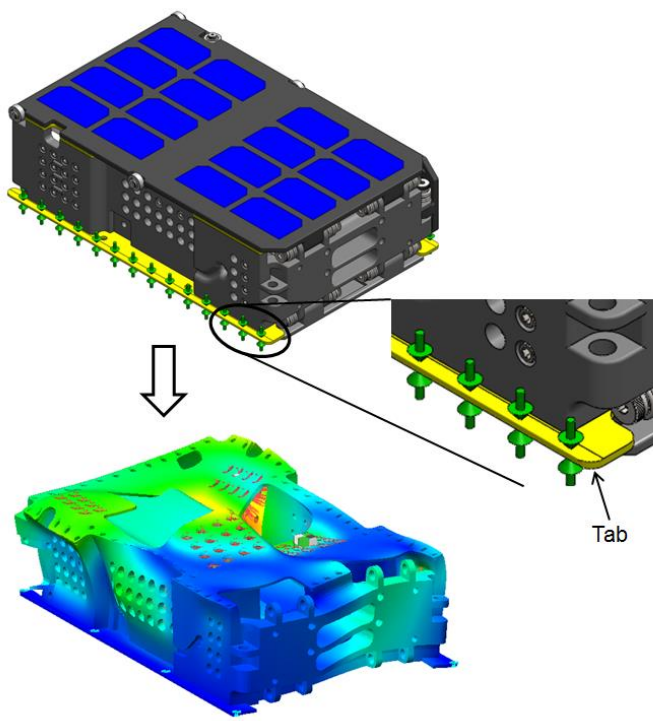


Figure 9-2: Prediction of 6U Dynamic Response

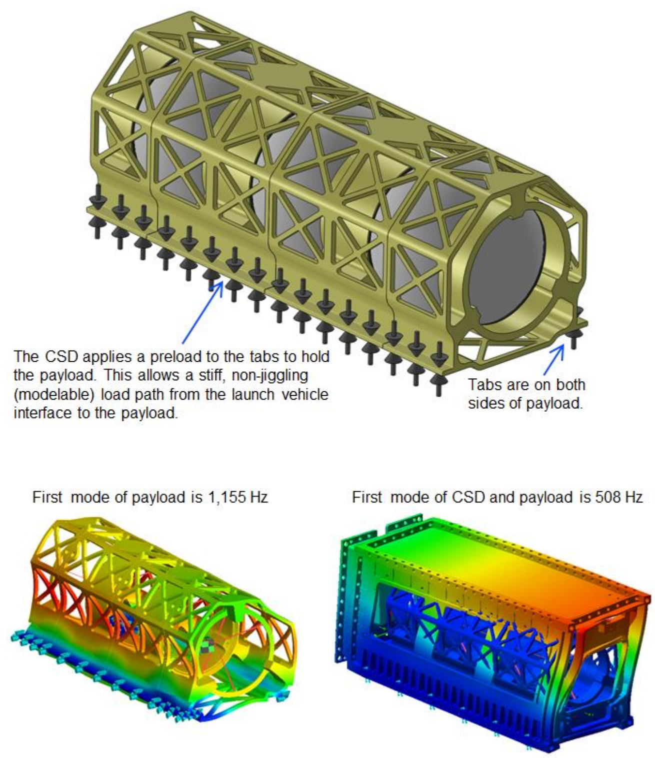
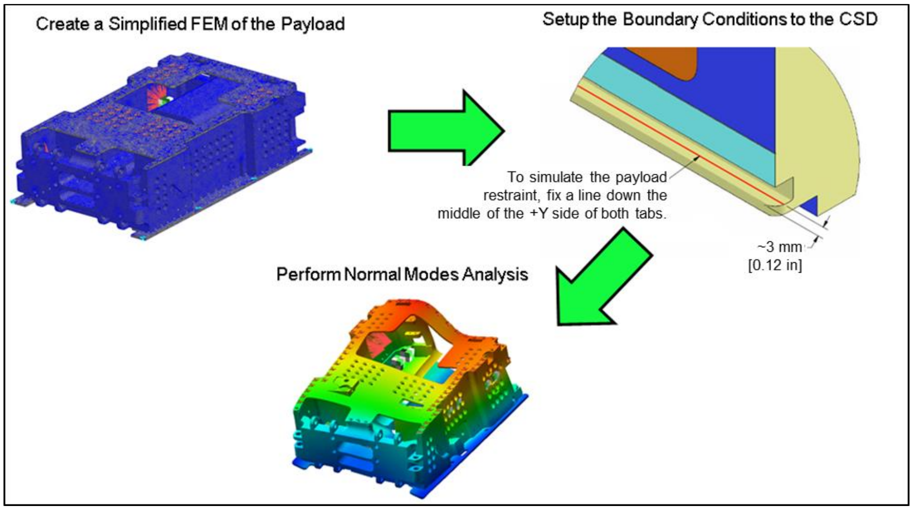


Figure 9-3: Prediction of 3U Dynamic Response

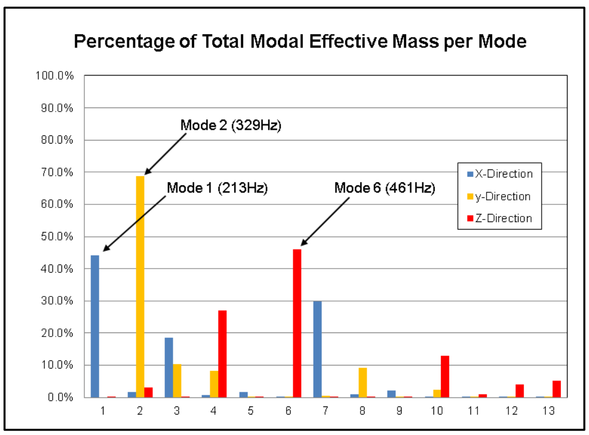
10. PREDICTING DESIGN LIMIT LOADS

The maximum structural loading typically results from the dynamic response during random vibration testing and/or shock testing. These loads are dependent on the mass, stiffness, and dampening properties unique to each payload. The method below provides a rudimentary means of predicting these loads.

1) Create a simplified model of the payload consisting of the primary structure and significant components for a Normal Modes Analysis from 20-2,000Hz.



2) Identify the dominant resonant frequencies and mode shapes for each orthogonal direction (X, Y, Z). These modes can be identified as having the highest percentage of Modal Effective Mass relative to all modes modeled within the frequency bandwidth stated above.



3) The response for a random vibration profile can be predicted by using the Miles Relation shown below:

$$\mathbf{Grms} = \sqrt{\mathbf{0.5 * \pi * f_n * Q * ASD}}$$

Grms [g] = 1σ acceleration response

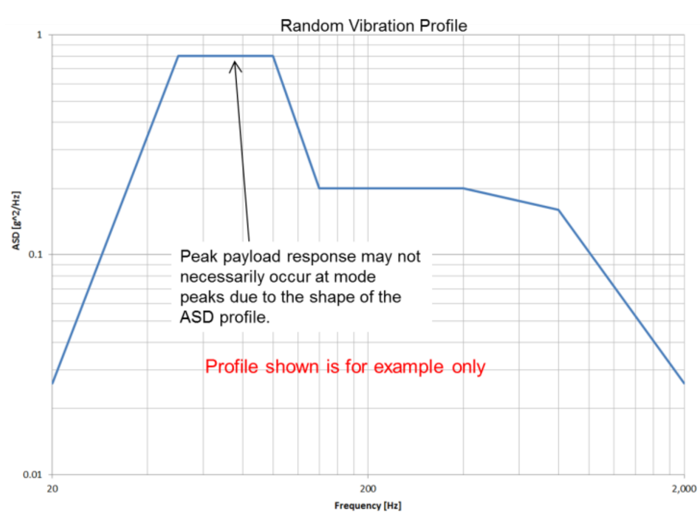
f_n [Hz] = natural frequency (frequency of selected mode)

Q [-] = $\frac{1}{2*\zeta}$ = quality factor (use 10 as an estimate if unsure)

ζ [-] = critical dampening

ASD [g^2/Hz] = input acceleration spectral density at the desired frequency f_n

Assume the peak response is 3σ = 3*G_{rms}



All payloads behave uniquely. The figure below shows two payload mockups of the same mass with very different responses. The mockup on the left has numerous discrete masses and bolted joints. There are many modes and the dampening is typical of many payloads. The mockup on the right consists of a few very stiff aluminum plates. There is one very dominate mode over a wide frequency range that results in significant loading.

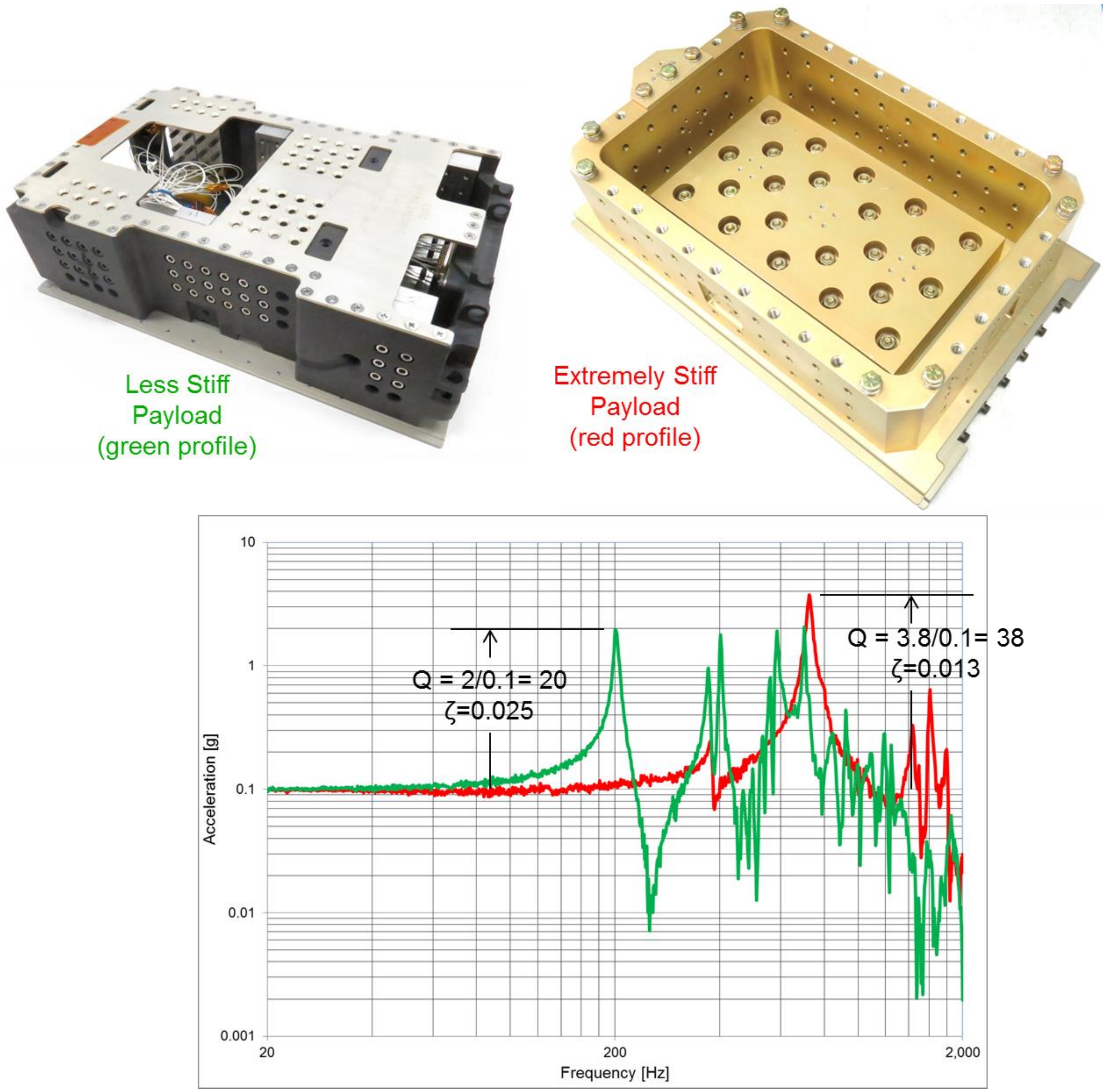


Figure 10-1: Comparison of Payload Responses

The response of the payload will significantly affect the loading on critical parts like reaction wheel bearings, complex mechanisms, electronic components and optics. Ensuring a consistent load path from the launch vehicle to the payload (i.e. preloading) is the only way to accurately predict the loading from thermal, vibration and shock.

11. TAB MANUFACTURING

Designing and manufacturing tabs that meet the requirements of this document are critical for successful integration and deployment of a payload. As the interface to the CSD, the tabs shall be designed, dimensioned, manufactured, and inspected with care.

Production Drawings

The figure below shows an example production drawing of a plate with tabs. Some of the tolerances are tighter than this specification requires. Also, the tabs do not have to be on a discrete plate as shown. They can be bolt-on features or machined into a more intricate structure.

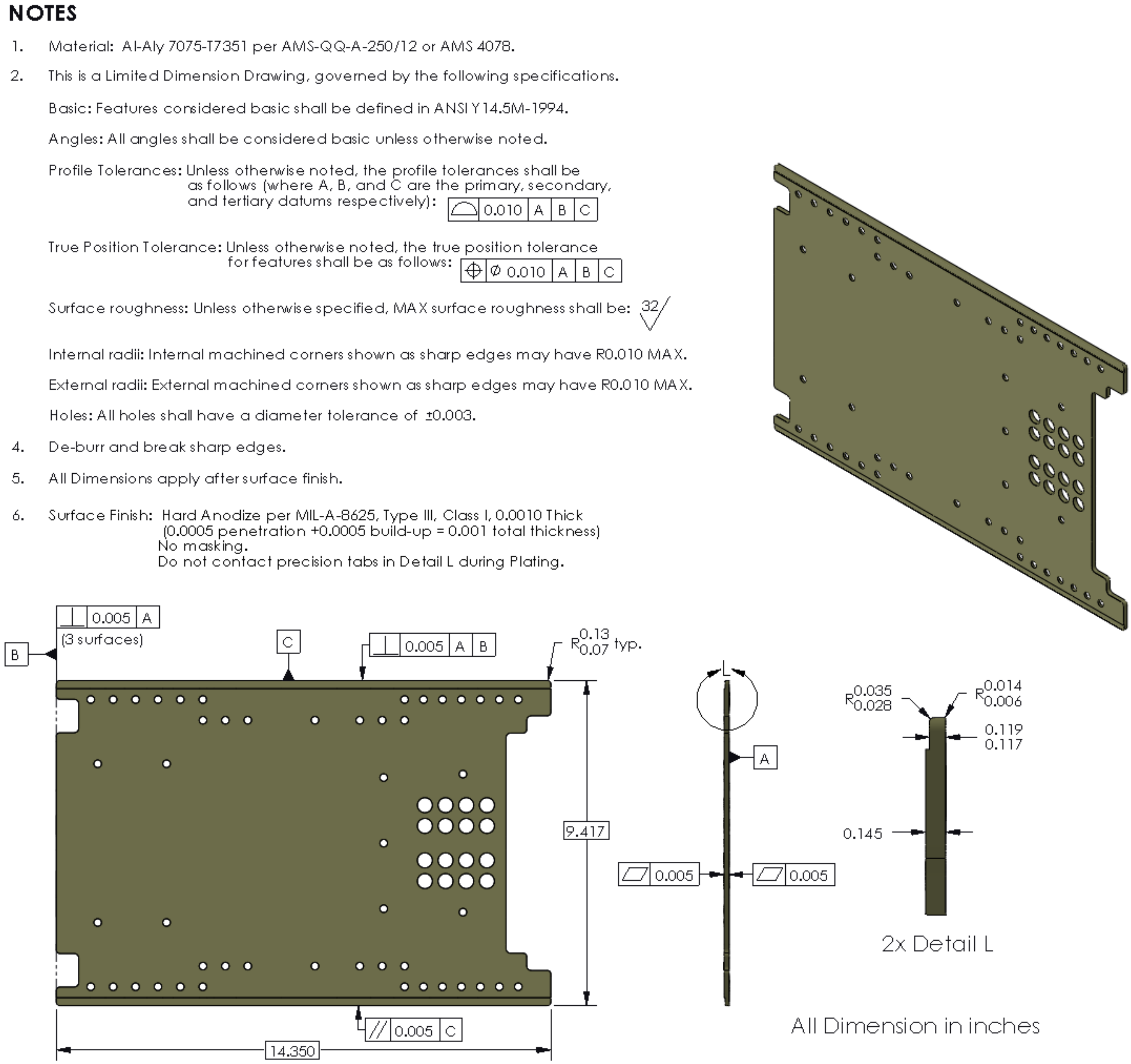


Figure 11-1: An Example Tab Production Drawing

Inspection

Measure the tab thickness using a micrometer as follows. A digital caliper lacks the required accuracy.

Figure 11-2: Measuring Tab Thickness with Micrometer

1) Select a micrometer with an accuracy and resolution of 0.00005 inches (0.001 mm).
2) Ensure micrometer surfaces and tabs are clean.
3) Use a gauge block to verify micrometer accuracy and operator technique.
4) Mark increments at every inch along tab length.
5) Take minimum three measurements at each location to ensure repeatability.
6) Record and plot measurements.
7) All measurements shall be within tolerance. The figure below shows an example of tabs that are NOT acceptable.

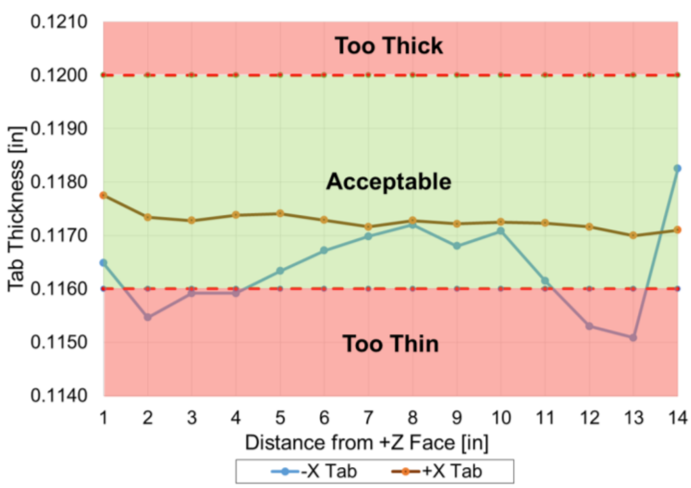


Figure 11-3: Tab Thickness Measurement

Also verify the following critical aspects of the tabs.
1) All edge fillets are in tolerance. See Detail L in Figure 11-1 for an example.
2) Hard anodize is continuous along entire tab surface (top, bottom and sides). Location defined as between M-N in Detail Tab in Figure 6-2.

After the payload structure is assembled the tabs shall remain flat per Figure 6-2. Place the payload on a verified flat surface (granite surface plates are ideal). A 0.010 inch thick feeler gage or gage pin shall not fit under any portion of the tab. See figure below.

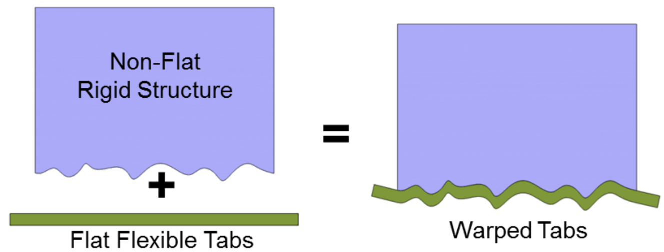


Figure 11-4: Example of Structure Warping Tabs

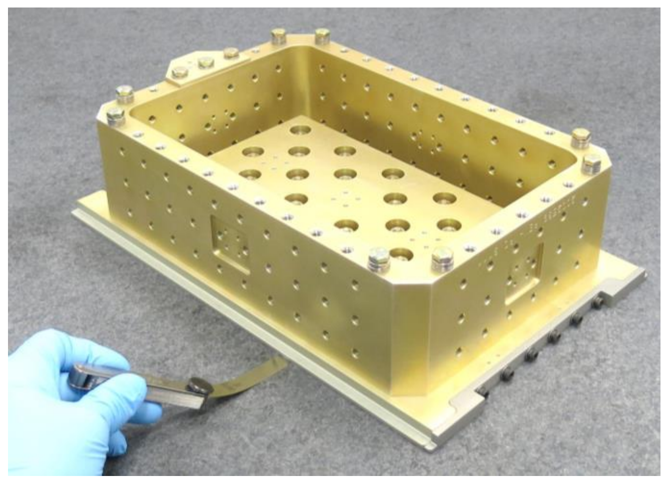


Figure 11-5: Verifying Assembled Flatness

The following figure is a worksheet that should be used when inspecting Tabs. Fill in the worksheet and verify that the measured values meet all the requirements defined within this document. The flatness and perpendicularity measurements shall be taken after the entire payload structure is assembled.

Item	Value
Tab material	
Tab anodize type and class	
Tab (datum A) flatness [mm or in]	
-Z face perpendicularity to datum A [mm or in]	

Width	
Location	Value [mm or in]
Back (near -Z side)	
Middle	
Front (near +Z side)	

Length	
Location	Value [mm or in]
Left (near -X side)	
Middle	
Right (near +X side)	

Distance from -Z face [mm (in)]	Thickness [mm or in]		Radius of Edge Fillets [mm or in]	
	-X Side	+X Side	-Y Side	+Y Side
13 (0.5)				
25 (1)				
51 (2)				
76 (3)				
102 (4)				
127 (5)				
152 (6)				
178 (7)				
203 (8)				
229 (9)				
254 (10)				
279 (11)				
305 (12)				
330 (13)				
356 (14)				

Figure 11-6: Tab Inspection Worksheet

12. CSD CONSTRAINED DEPLOYABLES

The payload may use the CSD to constrain deployables in designated areas as defined in the Parameters and Dimensions sections. At these designated contact zones the CSD interior surface shall be nominally 1.3mm[0.05 in] from the maximum allowable dynamic envelope of the payload defined as ‘Width’ and ‘Height’. Only the portion of the payload directly contacting the CSD Walls (bearing, etc.) may exceed the payload dynamic envelope.

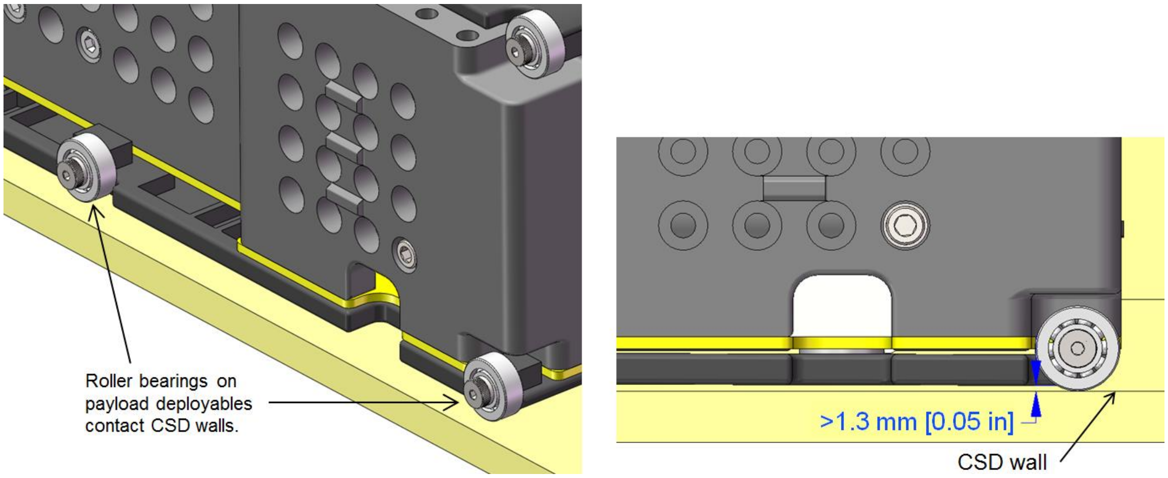


Figure 12-1: Deployable Contact with CSD

Deployables Design Notes:

- Ensure bearing spacing and panel stiffness are sufficient to prevent any portion of the panel from rubbing on the dispenser as the payload ejects.
- Deployables should have features to react shear loading at end opposite hinge. This prevents excessive loading on the hinge and deflection at the end of the deployable during launch.
- The deployable panels shall be sufficiently preloaded against the payload structure to minimize rattling during launch. This can be accomplished by incorporating a leaf spring, spring plunger, etc.
- Account for tolerance build-up in the deployable preload system. By necessity, the dispenser width will be greater than the tab width. During payload installation there could be up to 0.5mm [0.020 inches] of play relative to nominal in the +X or –X positioning of the payload. Therefore the +X or –X contact walls of the dispenser may be 0.8 to 1.8 mm [0.03 to 0.07 inches] from the payload’s nominal max dynamic envelope. These values are estimates. Refer to the dispenser manufacturer for specific values.

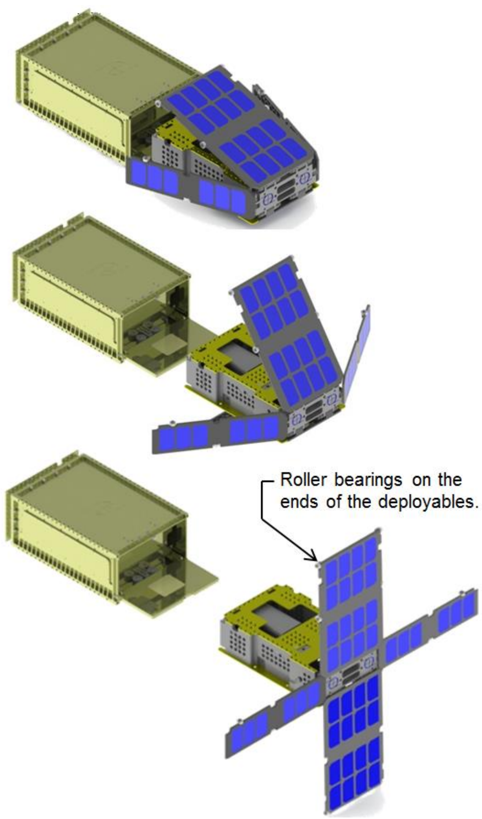


Figure 12-2: Payload Dispensing from CSD

13. PAYLOAD VOLUME

The allowable volume of the payloads is larger than existing CubeSats.

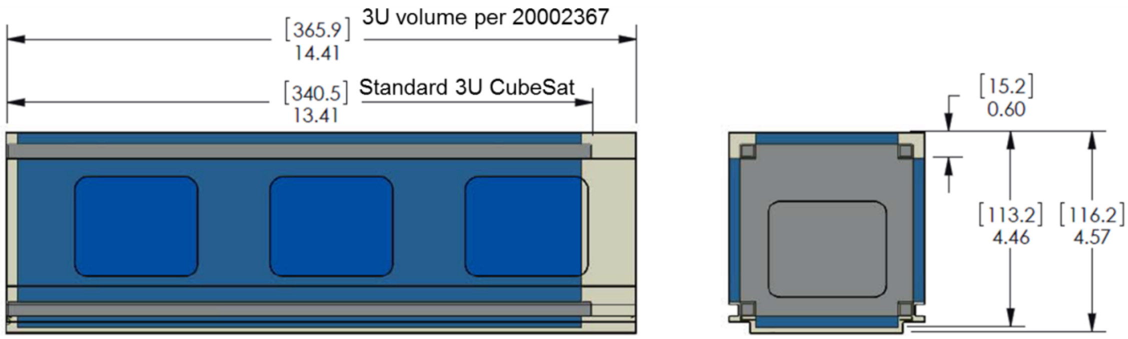


Figure 13-1: Comparison of 3U Payload Volumes. This specification allows 15% more payload volume.

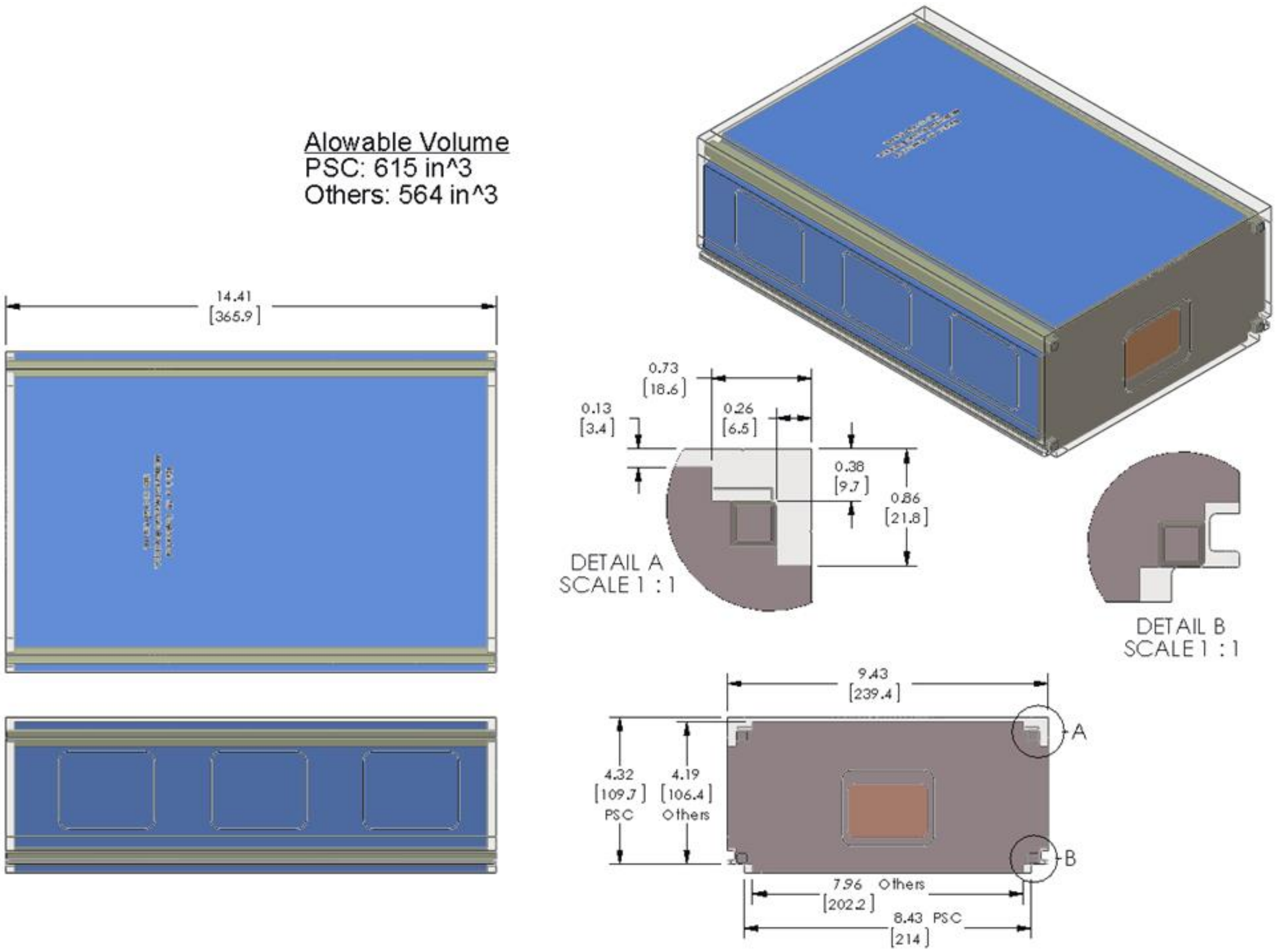


Figure 13-2: Comparison of 6U Payload Volumes. This specification allows 9% more payload volume.

14. TYPICAL APPLICATIONS

The payload need not occupy the entire volume as long as the tabs are present.

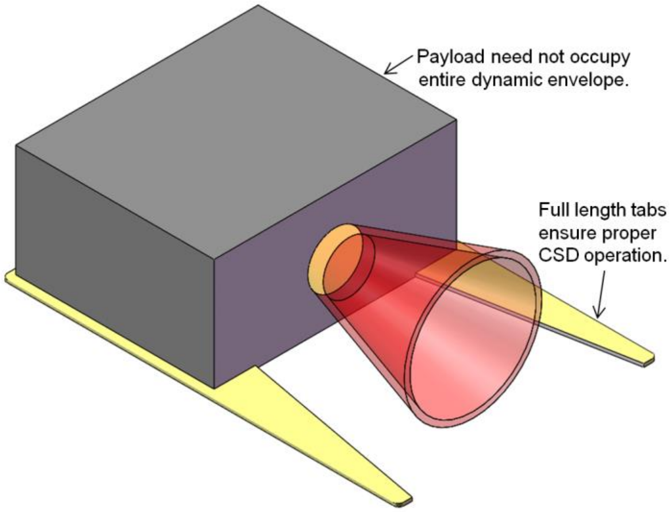


Figure 14-1: 6U Payload Example

Figure 14-2: POPACS, A Multi-Piece 3U Payload

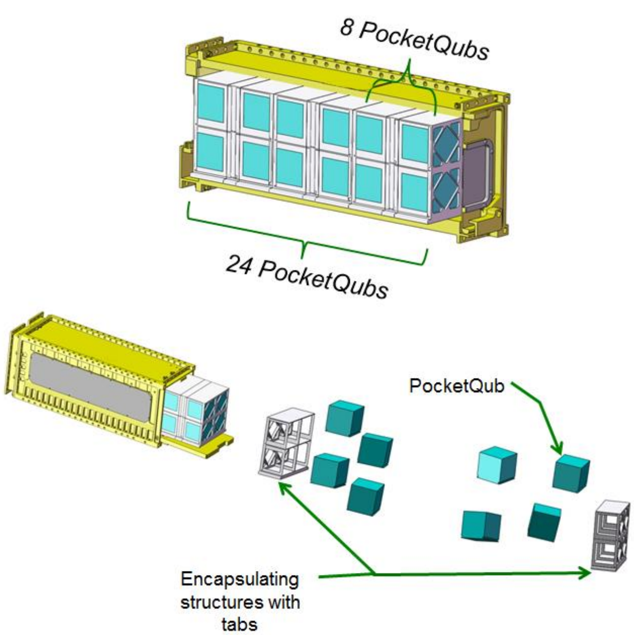


Figure 14-3: Encapsulating PocketQubs in a Tabbed Structure

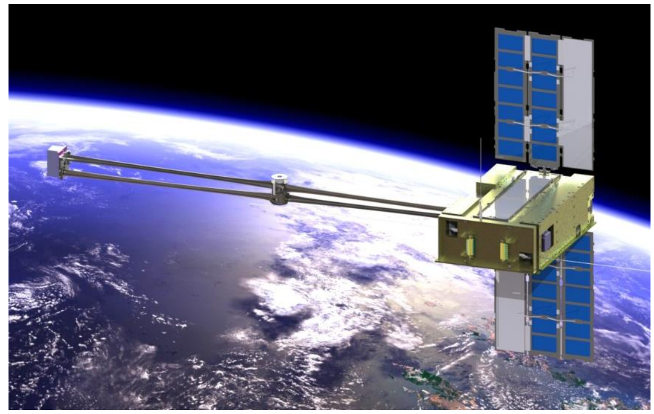


Figure 14-4: 6U Payload

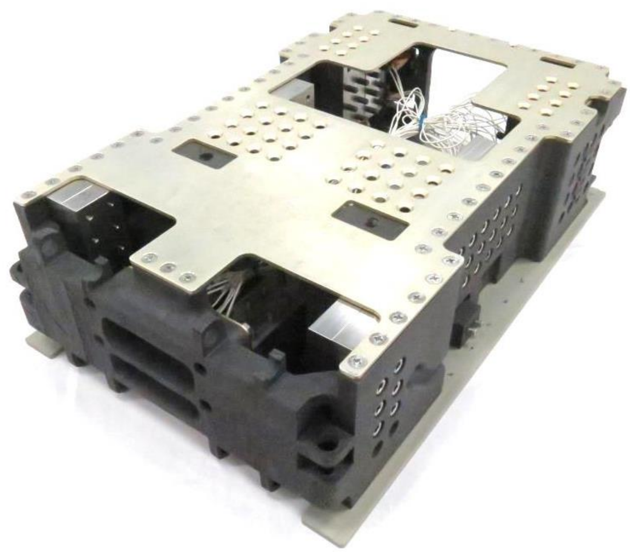


Figure 14-5: 3D Printed 6U Mockup Structure

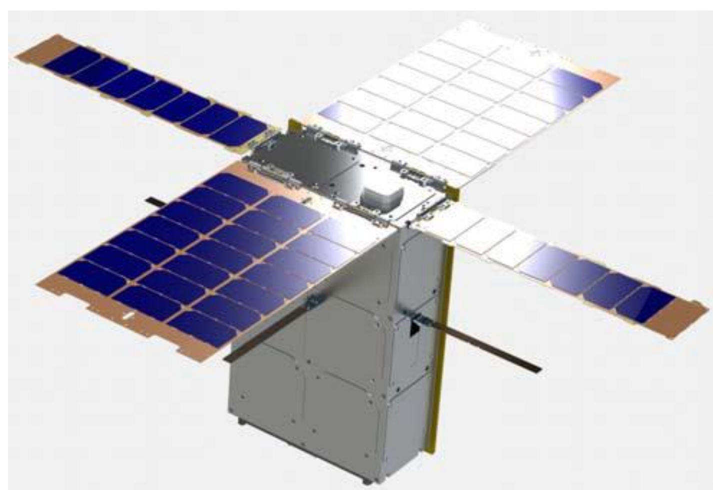


Figure 14-6: Pumpkin Inc.'s 6U SUPERNOVA Bus

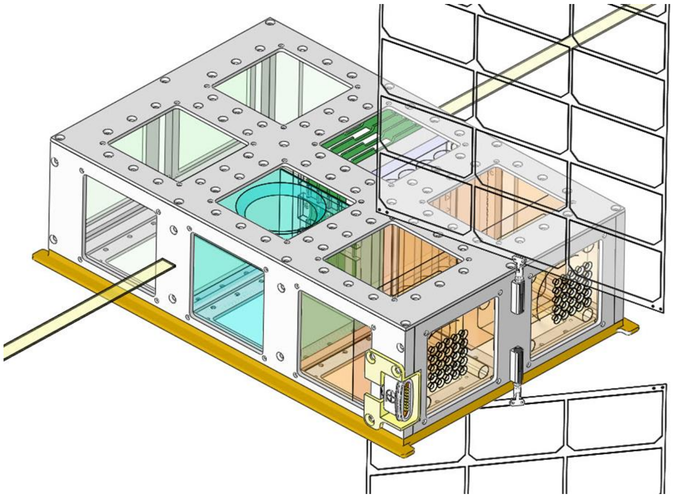


Figure 14-7: 6 X 1U Bus

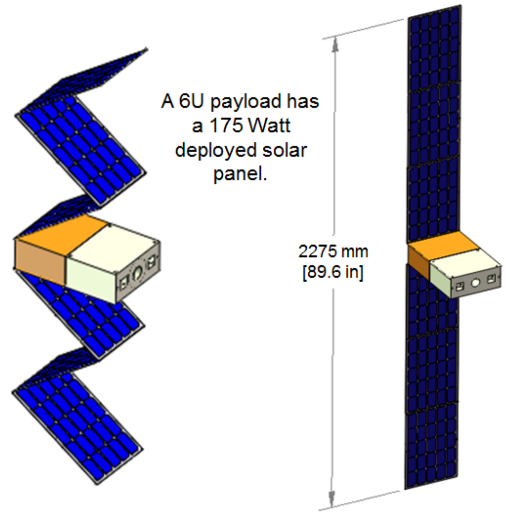


Figure 14-8: Solar Array Potential

An existing CubeSat with 4 corner rails can easily comply with this specification by fastening on custom tabs.

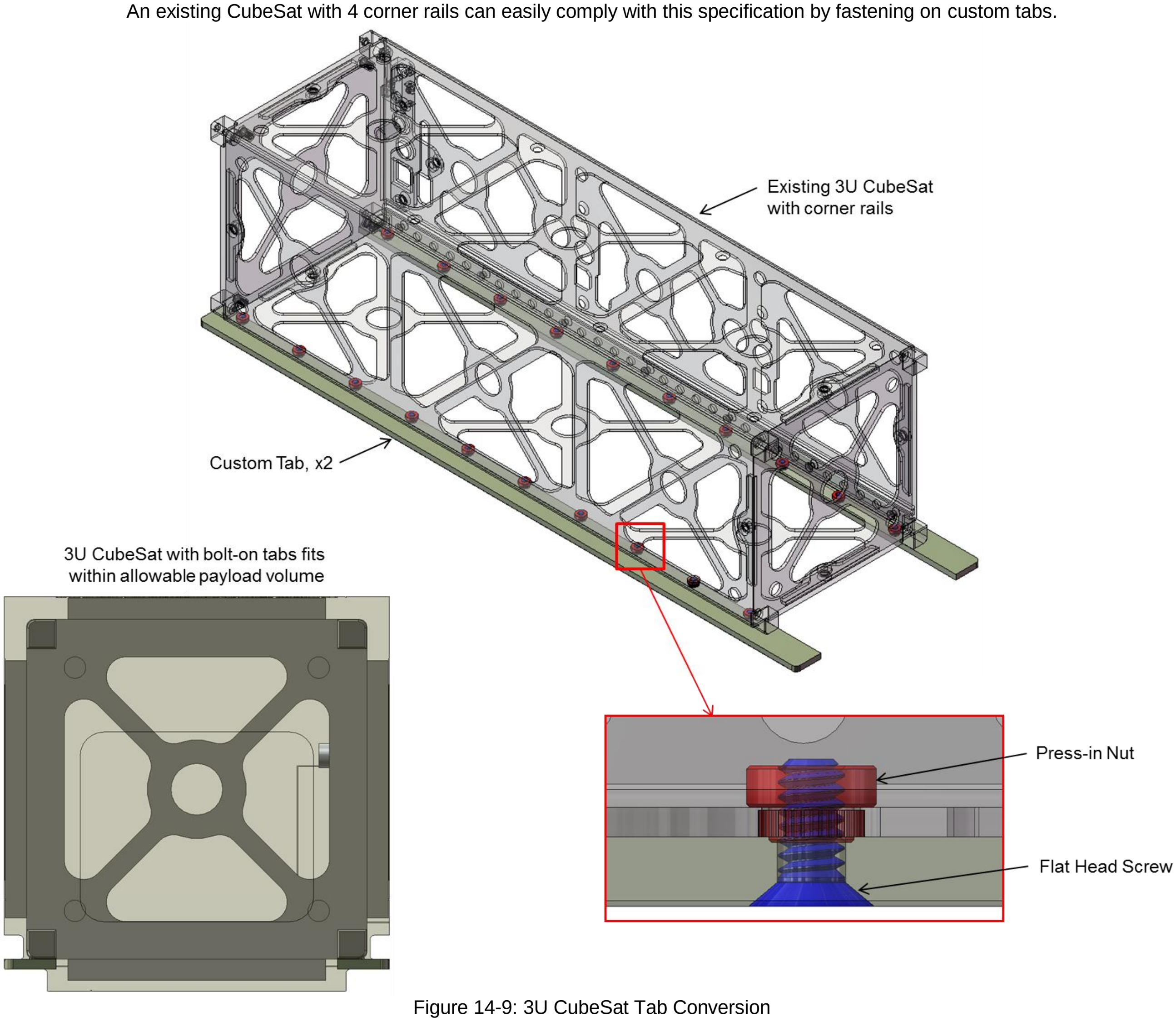


Figure 14-9: 3U CubeSat Tab Conversion

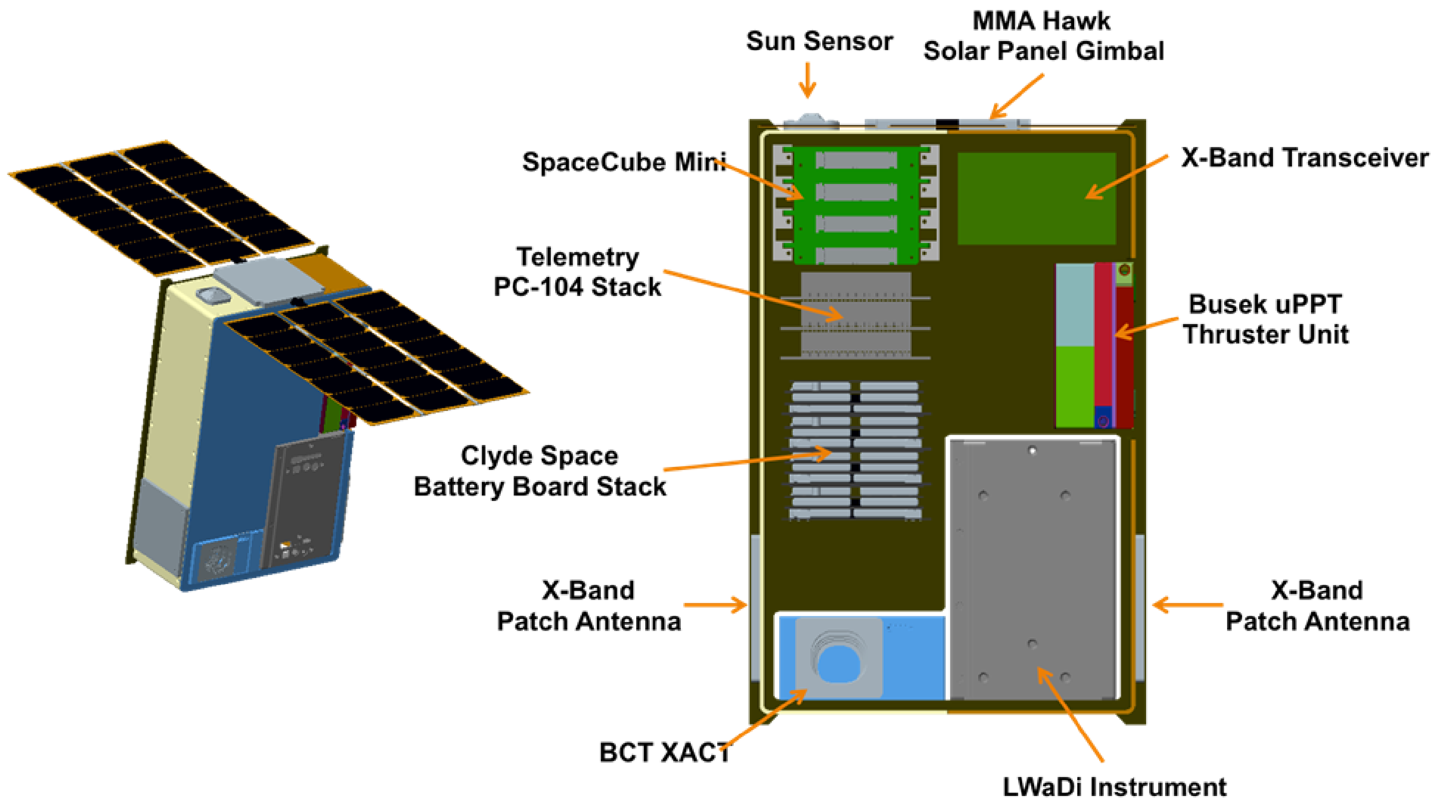


Figure 14-10: Lunar Water Distribution (LWADI), a 6U Interplanetary Spacecraft. Ref. 6.

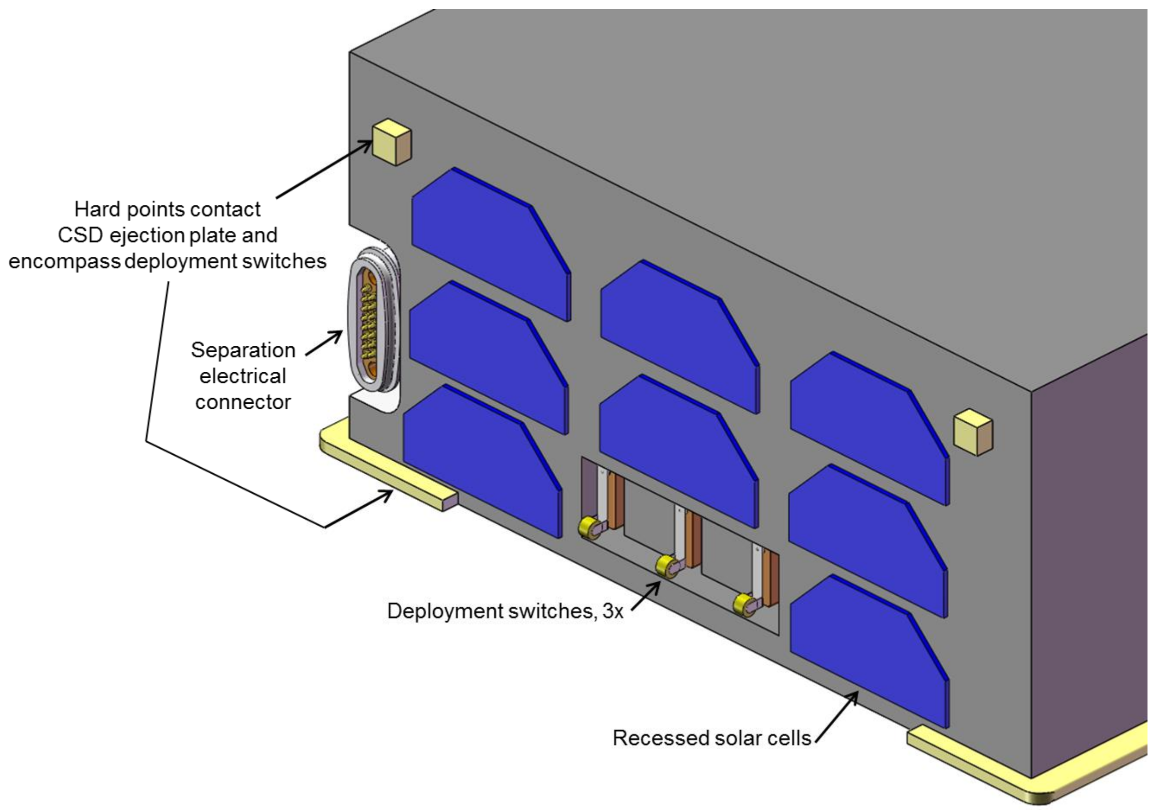


Figure 14-11: Example of -Z Face that Contacts Dispenser Ejection Plate

15. SEPARATION ELECTRICAL CONNECTOR ATTACHMENT

The figures below show a typical means of mounting the separation electrical connector. It only need be mounted via the flat face that contains the two #4 screws. Additional support around the side of the connector shell is unnecessary. An open cutout in the mounting bracket is beneficial as it allows the connector to be removed after the harness is wired.

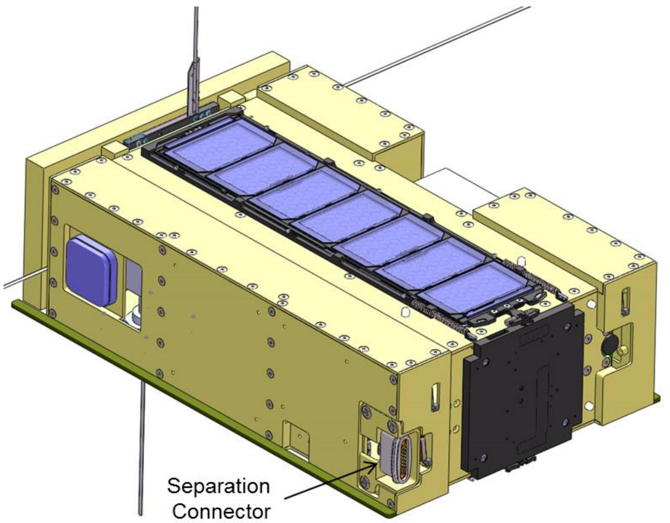


Figure 15-1: Separation Electrical Connector on Payload

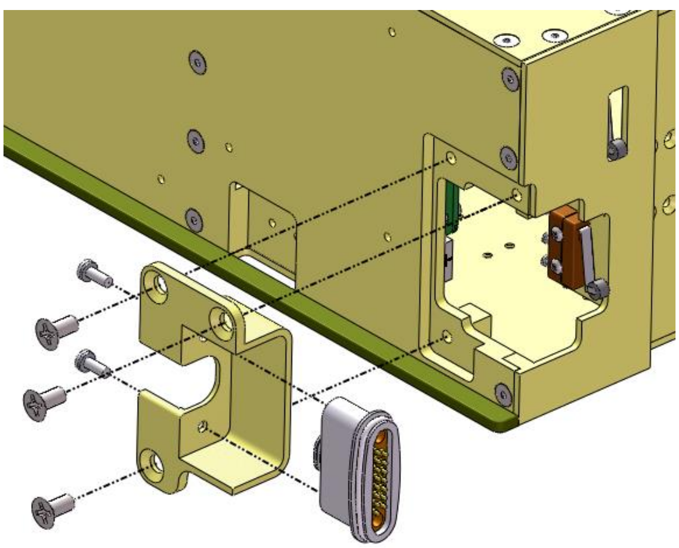
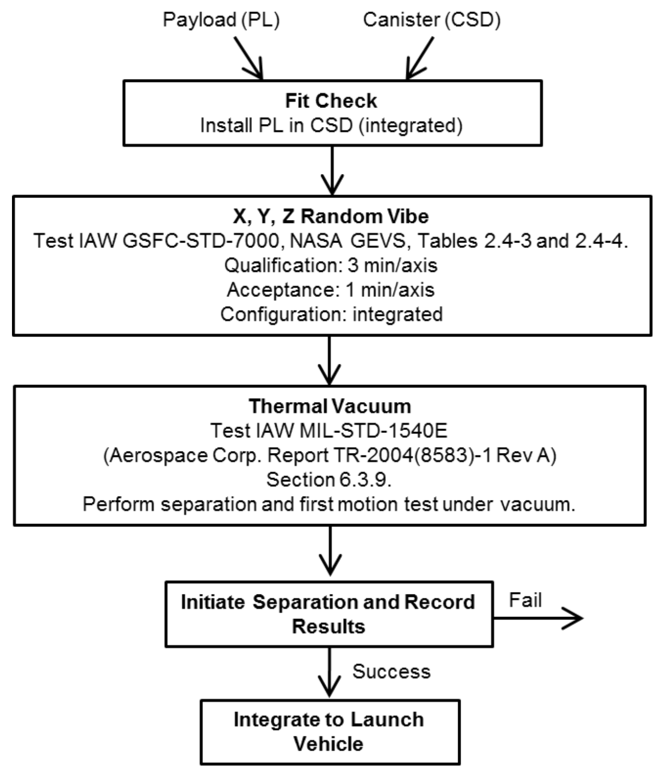


Figure 15-2: Separation Electrical Connector Mounting Example

16. RECOMMENDED TEST AND INTEGRATION

Test levels are for launch environment, not necessarily on-orbit.



17. TIPS AND CONSIDERATIONS

1. Electrical Wiring: Include the electrical harness in the CAD model. Ensure there are sufficient routing options, strain relief and clearances. Also, the harness can consume a significant portion of the allowable payload mass.
2. Installation in CSD: The payload may end up being installed vertically in the CSD (gravity in –Z). Add a removable handle on the +Z face to aide installation.
3. CSD Ejection: When possible, verify complete ejection of the payload from the CSD during testing.

18. CAD MODELS

Solid models of the payloads at their maximum dynamic envelope are available for download at www.planetarysys.com.

19. ADDITIONAL INFORMATION

Verify this is the latest revision of the specification by visiting www.planetarysys.com.

Please contact info@planetarysystemscorp.com with questions or comments. Feedback is welcome in order to realize the full potential of this technology.

20. REFERENCES

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21. ACKNOWLEDGEMENTS

Dr. Andrew Kalman, Pumpkin Inc.	Adam Reif, Pumpkin Inc.
Shaun Houlihan, Pumpkin Inc.	Hans-Peter Dumm, AFRL
Steve Buckley, ORS	Dr. Jeff Welsh, ORS
Craig Kief, COSMIAC	Dr. Eric Swenson, AFIT
Philip Smith, AFIT	Dr. Jordi Puig-Suari, CalPoly
Roland Coelho, CalPoly	Dr. Robert Twiggs, Morehead State
Gil Moore, Project POPACS	Rex Ridenoure, Ecliptic Enterprises
Tom Walkinshaw, Pocketcubeshop	Jason Armstrong, ORS

22. REVISION HISTORY

Revision	Release Date	Created By	Reviewed By
-	25-Jul-2012	RH	WH
A	06-Aug-2013	RH	WH
B	21-Jul-2014	RH	WH
C	3-Aug-15	HM	WH

Changes from previous revision:

Section(s)	Changes
All	- Added numbering to sections
2, 6, 7	- Updated Figures 2-2, 6-1, 6-2, 6-3, and 7-1
4. Common Requirements	- Added note that countersinks and other features are prohibited along tabs - Changed max surface roughness of tabs to 1.2 µm Ra - Added deployment switch requirement
11. Tab Manufacturing	- Inserted tab inspection worksheet
12. CSD Constrained Deployables	- Added tolerance to deployable gap
13. Payload Volume	- Added note that all parts of payload must remain inside payload volume at all times
14. Typical Applications	- Updated Figure 14-9
20. References	- Added 7 - 11